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Unlocking Nature's Fertilizers: Exploring Potassium Solubilizing Bacteria

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Abstract:-

Potassium is one of the essential macronutrients for plant growth and development, playing a crucial role in various physiological processes such as enzyme activation, photosynthesis, and nutrient transportation. However, a significant portion of soil potassium exists in insoluble forms, making it inaccessible to plants. Enter Potassium Solubilizing Bacteria (KSB) - a group of remarkable microorganisms capable of converting insoluble potassium into forms that plants can readily absorb. The potential of KSB to enhance soil fertility and boost crop yields has garnered significant interest in agricultural research and sustainable farming practices. By harnessing the natural capabilities of these bacteria, farmers can reduce their dependence on chemical fertilizers, leading to more eco-friendly and cost-effective farming solutions. This discovery not only promises to revolutionize traditional farming methods but also contributes to the broader goal of sustainable agriculture. In this article, we delve into the fascinating world of potassium solubilizing bacteria, exploring their mechanisms of action, methods for their screening and their potential applications in agriculture. Join us as we unlock nature's secret to more productive and sustainable farming.

Introduction:

Potassium (K) solubilization is done by a wide range of saprophytic bacteria, fungal strains and Actinomycetes. There are strong evidences that soil bacteria are capable of transforming soil K to the forms available to plant effectively.

There is considerable population of KSB in plant rhizosphere. These include both aerobic and anaerobic isolates however the most frequently KSB in soil are aerobic in nature. A considerably higher population of KSB is commonly found in the rhizosphere in comparison with non-rhizosphere soil.

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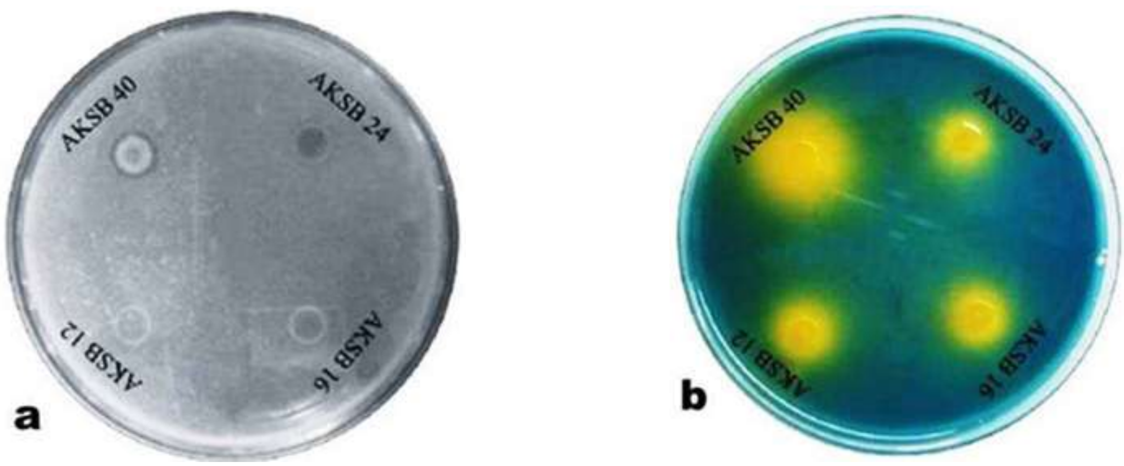
Solubilization of K by KSB from insoluble and fixed forms is an import aspect regarding K availability in soils. The ability to solubilize the silicate rocks by *B. mucilaginosus*, *B. circulanscan*, *B. edaphicus*, *Burkholderia*, *A. ferrooxidans*, *Arthrobacter* sp., *Enterobacter hormaechei*, *Paenibacillus mucilaginosus*, *Cladosporium*, *Aminobacter*, *Sphingomonas*, *Burkholderia* and *Paenibacillus glucanolyticus* has been reported.

$MgSO_4.7H_2O$; 0.1 g $CaCO_3$; 0.006 g $FeCl_3$; 2.0 g $Ca_3(PO_4)_2$; 3.0 g potassium aluminium silicate; and 20.0 g agar in 1 L of deionized sterile water. The pH of this medium is adjusted to 7.2 by adding 1 N NaOH. The plates are incubated at 28 ± 2°C in biological oxygen demand incubator for 3-4 days. The colonies exhibiting clear zones are selected and diameter of the solubilization zone is calculated and the values are recorded for each sample.



K solubilization on Aleksandrov agar plate   K solubilization on modified agar medium plate

Figure 1. Comparison of Potassium Solubilization on Aleksandrov Agar Plate (a) and Modified Agar Medium Plate (b) After 72 Hours of Incubation

Among the soil bacterial communities, *B. mucilaginosus*, *B. edaphicus* and *B. circulanscan* have been described as effective K solubilizers. KSB are usually present in all soils and have been isolated from rhizosphere soil, non-rhizosphere soil, paddy soil and saline soil. KSB are isolated by serial dilution plate method using modified Aleksandrov medium including 5.0 g glucose; 0.5 g

Recently, a modified plate assay for rapid screening of KSB has been developed. This assay is based on improved visualization of halo zone formation around the colonies on agar plates, through inclusion of an acid-base indicator dye (bromothymol blue, BTB), to modify the Aleksandrov medium. This assay is time saving, more sensitive and beneficial in comparison to the Aleksandrov plate assay.

Quantitative estimation of K solubilization is performed by flame photometry wherein culture broth is centrifuged and supernatant is used for precipitation of cobalt nitrite. Standard curve for quantification of K is prepared using various concentrations of KCl solution. In this assay, mica is usually used as a source of insoluble form of K, although other K sources were also used in screening KSB (e.g., insoluble magnesium trisilicate, muscovite, illite powder, montmorillonite, kaolinite, potassium-feldspar, biotite, waste mica, bentonite, wood ash and potassium aluminium silicate). In addition, the amount of K solubilization in different culture media (e.g., different pH, temperature, K source, and carbon source) is different. For example, the amount of K solubilization by *B. edaphicus* in the liquid media was more and a better growth was detected on illite than feldspar. In general, the microbial solubilization of K is strongly influenced by pH, oxygen, the bacterial strains used and kind of K bearing minerals; in fact, moderate alkalinity favours the solubilization of silicate.

Mechanisms of K solubilization by KSB

It is generally believed that microorganisms contribute to the release of K^+ from K-bearing minerals by several mechanisms. Released H^+ can directly dissolve the mineral K as a result of slow releases of exchangeable K, readily available exchangeable K. As occurs in the case of P solubilization, the major mechanism of K mineral solubilization is by production the organic and inorganic acids and production of protons (acidolysis mechanism) which are able to convert the insoluble K (mica, muscovite, and biotite feldspar) to soluble forms of K, easily taking up by the plant.

The types of various organic acids such as oxalic acid, tartaric acids, gluconic acid, 2-ketogluconic acid, citric acid, malic acid, succinic acid, lactic acid, propionic acid, glycolic acid, malonic acid, fumaric acid, etc. have been reported in KSB, which are effective in releasing K from K-bearing minerals. It has also observed that the type of the organic acid produced by KSB is different. Among the different organic acids involved in the solubilization of insoluble K, tarteric acid, citric acid, succinic acid, α-ketogluconic acid and oxalic acid are the most prominent acids released by KSB.

Microbial decomposition of organic materials also produces ammonia and hydrogen sulfide that can be oxidized in the soil to form the strong acids such as nitric acid and sulphuric acid. Hydrogen ions displace K^+, Mg^{2+}, Ca^{2+} and Mn^{2+} from the cation exchange complex in a soil. In addition to decreasing soil pH, organic acids produced by KSB can release of K ions from the mineral K by chelating (complex formation) Si^{4+}, Al^{3+}, Fe^{2+} and Ca^{2+} ions associated with K minerals. It was reported that KSB weathered phlogopite via aluminum chelation and acidic dissolution of the crystal network. In addition, The *B. altitudinis* strain accelerates weathering of K feldspar, change mineral surface morphology and induce the formation of new mineral complex. This strain dissolved K feldspar and significantly released more Si, Al and Fe by producing more organic acids. The KSB have a considerable role in proving K to plant by storing K in their biomass, which is potentially available to plants. It has been reported that the production of various extracellular polymers (primarily proteins and polysaccharides) can also led to release of K from K bearing minerals. These substances serve as attachment structures to mineral surface. Solution containing fresh microbial exopolysaccharides increases the dissolution rate of feldspars probably by forming complexes with framework ions in solution. KSB also synthesize biofilms, which create controllable microenvironments around microbial cells for weathering. Biofilm formation on aluminosilicate increases the residence time of water as compared to the residence time at the bare mineral surface and enhances the mineral weathering.

It was accepted that the microbial biofilms not only accelerated the weathering process but also regulated denudation losses by acting as a protective layer covering the mineral-water-hyphal/root hair interface in the mycorrhizosphere and rhizosphere of vascular plants. Besides, biofilm formation on mineral surface promoted the corrosion of potassium rich shale and the release of K, Si and Al in the bacteria-mineral contact model. In addition, it is known that the release of organic acids from the plant roots can be effective in enhancing mobilization of mineral K. Therefore, it can be suggested that other PGPRs (e.g., IAA producing bacteria) can also have a role in providing K for plant by increasing root exudates. In general, the most important mechanisms known in K mineral solubilization by KSB are (i) by lowering the pH; (ii) by enhancing chelation of the cations bound to K; and (iii) acidolysis of the surrounding area of microorganism.

Potentialities of KSB

KSB can accelerate weathering of K minerals; especially when they are in direct contact with mineral surfaces by different action mechanisms. Attempts have been made to use of K mobilizing bacteria for solubilizing K from different K bearing minerals and hence to improve plant nutrition. Although KSB could be an alternative and viable technology to solubilize insoluble K into soluble form. The application in agricultural practice is still prevented by several factors, example, (i) lack of awareness about bio-fertilizers amongst the farmers; (ii) slow influence of the K biofertilizer on crop yield; (iii) less interest in scientific community on the development of K biofertilizer technologies; (iv) culture collection banks not yet developed for KSB due to the loss of efficient strains developed by scientists; and (v) and deficiency in technology in respect to product formulations are the major limitations.

Conclusions

K-bearing minerals significantly contribute to potassium (K) fertilization for crop plants, which can only absorb K from the soil solution. While K can be released into the soil solution from insoluble minerals, this release is typically insufficient to meet plant requirements due to the low concentration of soluble K and its relative immobility in the soil. Consequently, K-containing fertilizers are commonly applied in extensive agricultural systems to supply available K. However, these fertilizers are expensive and their long-term use leads to increased input costs, reduced agricultural profitability, and numerous environmental problems due to the accumulation of heavy metals in the soil and plant systems. The use of potassium solubilizing bacteria (KSB) offers a promising alternative to solubilize soil K reserves and make them available to plants, thereby promoting plant growth and reducing the need for K-fertilizers. K solubilization is facilitated by a variety of bacteria, including *B. mucilaginosus, B. edaphicus, B. circulans, Pseudomonas, Burkholderia* and *Acidithiobacillus ferrooxidans*. Research has demonstrated that KSB can dissolve K from insoluble K-bearing minerals by secreting organic acids. The primary mechanism through which KSB make K available to plants involves the production of organic acids, which can either directly increase dissolution through proton or ligand-mediated mechanisms or indirectly by forming complexes in solution with reaction products. Thus, applying KSB as biofertilizers not only enhances plant growth and yield but also reduces the need for agrochemicals, supporting eco-friendly crop production. These technologies are becoming increasingly vital in modern agricultural practices, especially given the changing agricultural landscape and environmental hazards associated with chemical fertilizers, which call for a greater role for biofertilizers in the future.

Future Perspectives

To realize the potential of KSB, several areas of research and application need to be explored:

1. Conduct field studies to assess the potential of KSB techniques in agricultural production systems and evaluate their impacts on crop growth and soil behaviour.

2. Investigate the role of KSB in increasing the availability of other nutrients affected by pH, such as phosphorus (P), nitrogen (N), iron (Fe), and zinc (Zn).
3. Study the effects of other plant growth-promoting rhizobacteria (PGPRs) such as indole-3-acetic acid (IAA) producers, ACC deaminase producers, phosphate solubilizers, and nitrogen fixers on K availability.
4. Examine the interactions (both positive and negative) between KSB and other PGPRs concerning K availability.
5. Determine the optimal conditions for KSB activity, including the role of organic matter.
6. Evaluate plant species that are effective in K uptake and support K solubilizing microbes.
7. Understand the mechanisms of KSB to determine the best bacterial strains for use with specific plants in various geographic regions.
8. Study the stability of KSB inoculants in the soil and assess soil mineralogical properties.
9. Conduct further research on the molecular biology of KSB, as there is currently limited information available as compared to other PGPRs. Addressing these areas will enhance understanding and application of KSB in sustainable agriculture.